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Recognition of Concealed Information with Behavioral and Spectral Analyses

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The main thesis of this project was that individuals who have concealed information can be detected using a combined behavioral and psychophysiological approach. This study examined the similarities and differences that characterize the behavioral and power spectra responses in truthful and deceptive subjects. Half of the subjects participated in a mock crime while the other half participated in a non-crime scenario. The participants responded during their session to words related and not related to the scenarios they enacted. Although the participants in the mock-crime group were instructed to deny knowledge of any words related to their scenario, the behavioral and spectral data demonstrate that they actually possess concealed information. Therefore, behavioral and spectral indices elicited by concealed information in deceptive subjects can reflect some aspects of deceit. A quasi- replication of the initial experiment was then performed to examine the nature of the power spectra effects. The same protocol was used, except that a block format was used for stimulus presentation and the analysis window for the power spectra was expanded and all frequencies between 13 and SOHZ were available for analysis rather than analyzing the peaks and valleys alone. The results showed that indeed there were significant Group by Frequency effects which indicated that the power spectra of deceivers differed from those of nondeceivers. However, there was neither an Electrode by Group nor an Electrode by Frequency by Group effect that would have reinforced the power spectra differences found in the initial experiment. Although the details of the power spectra effects are yet to be resolved with further study, both experiments described in this Final Report revealed interaction effects, with Group that support the conclusion that power spectra can potentially identify whether an individual is or is not concealing information from their Examiner.

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Abstract

LAWSON, A. L. & PRATARELLI, M. E.. Recognition of Concealed Information with Behavioral and Spectral Analyses. August, 1999, Report no. DoDPI97-P-0017. Department of Defense Polygraph Institute, Fort Jackson, SC, 36205.--The main thesis of this project was that individuals who have concealed information can be detected using a combined behavioral and psychophysiological approach. This study examined the similarities and differences that characterize the behavioral and power spectra responses in truthful and deceptive subjects. Half of the subjects participated in a mock crime while the other half participated in a non-crime scenario. The participants responded during their session to words related and not related to the scenarios they enacted. Although the participants in the mock-crime group were instructed to deny knowledge of any words related to their scenario, the behavioral and spectral data demonstrate that they actually possess concealed information. Therefore, behavioral and spectral indices elicited by concealed information in deceptive subjects can reflect some aspects of deceit. A quasi-replication of the initial experiment was then performed to examine the nature of the power spectra effects. The same protocol was used, except that a block format was used for stimulus presentation and the analysis window for the power spectra was expanded and all frequencies between 13 and 50Hz were available for analysis rather than analyzing the peaks and valleys alone. The results showed that indeed there were significant Group by Frequency effects which indicated that the power spectra of deceivers differed from those of nondeceivers. However, there was neither an Electrode by Group nor an Electrode by Frequency by Group effect that would have reinforced the power spectra differences found in the initial experiment. Although the details of the power spectra effects are yet to be resolved with further study, both experiments described in this Final Report revealed interaction effects with Group that support the conclusion that power spectra can potentially identify whether an individual is or is not concealing information from their Examiner.

Descriptors: Lie detection, Spectral analysis, EEG, FFT, Concealed Information

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Introduction

Several psychometric electrophysiological devices that measure central nervous system (CNS) activity, e.g., EEGs have recently been studied in the hopes of locating a specific cognitive process that indexes deception (Bashore & Rapp, 1993; Rosenfeld, Nasman, Whalen, Cantwell, & Mazzeri, 1987). Although an accurate and reliable way to use the EEG has not yet been found, future prospects of using it to distinguish deception from nondeception appears promising. In the present study, behavioral and spectral EEG responses were employed in an attempt to distinguish guilty subjects who had participated in a mock crime from innocent subjects who performed a scenario containing no deceptive acts.

The approaches currently used in the application of EEG evolved from the use of event-related brain potentials (ERPs) as indices of deception. Previous ERP research in detecting deception has focused on the P300 and N400 windows (Allen, Iacono, & Danielson, 1992; Boaz, Perry, Raney, Fischler, & Shuman, 1991; Farwell & Donchin, 1991; Rosenfeld et al., 1987; Rosenfeld et al., 1988; Stelmack, Houlihan, & Doucet, 1996). These studies have focused on detecting deception by examining ERPs elicited by familiar, unfamiliar, and probe stimuli in light of a subject's behavioral response to the stimuli.

Rosenfeld et al. (1987) examined differences in post-stimulus ERPs between 400 and 700 ms related to a chosen item and eight novel items. A mock crime involving theft was constructed and subjects were asked to take one item out of a box containing nine items. Following the mock theft, ERPs were recorded while subjects were shown words on a screen of their chosen item, as well as eight novel items that they had not previously seen. Results revealed a significant difference ($p < .001$) between the ERP averages concerning chosen versus novel items. Specifically, positive peaks, either being distinct P300 waves or a broad positive area, were found in response to chosen items. However, novel item responses did not show consistent positivity during the critical time period. Thus, ERPs reveal that cognitive processing of verbal stimuli is different for familiar versus relatively unfamiliar stimuli. Rosenfeld et al.'s (1987) finding supports previous studies concerning an oddball paradigm in which a familiar item evokes a P300 when contrasted with several non-familiar stimuli (Duncan-Johnson & Donchin, 1979).

Farwell and Donchin examined crime-related scenarios and subjects with a criminal past history to explore whether the P300 could accurately detect deception (1991). Two groups of subjects were used where each group was guilty of committing one mock crime, but not the other. Stimuli consisted of phrases relevant to each scenario and arbitrary phrases (targets) that each subject rehearsed and was instructed to detect. Results found the P300 index distinguished between familiar and unfamiliar phrases by being elicited to familiar phrases only. Also, using a bootstrapping procedure, the P300 distinguished between familiar and unfamiliar phrases in 83 percent of the trials.

The N400 ERP component has been found in response to unexpected or inappropriate linguistic or semantic contextual violations (Kutas & Hillyard, 1980; Pratarelli, 1994; Boaz et al., 1991). For example, "roses are red" is a common phrase with red being commonly associated with roses but, "roses are black" is a contextual violation since roses are not commonly associated

with the color black. In lie detection, the N400 should be elicited when a participant with knowledge of a crime related event is given a false sentence related to that crime, i.e. a contextual violation relative to that crime. The N400 should not be elicited if a participant does not have knowledge of a crime related event (Boaz et al., 1991).

Collectively, the literature reporting the use of ERPs for detecting concealed knowledge, deception, or guilt reflects the promising use of CNS measures. Accordingly, ERPs appear well suited for guilty knowledge test (GKT) scenarios in which specific crime-related information is available. ERPs do not appear, as yet however, to be well suited for the types of general issue testing that is commonly performed by polygraph tests where little or no knowledge of a crime is available. Therefore, the conventional methods of analyzing ERPs using the late occurring potentials, like the P300 or N400 waves, are a small improvement over conventional psychophysiological detection of deception (PDD) polygraph methods. It was the goal of the present study/ thesis to explore other methods of utilizing the EEG in lie detection.

The current study is important in that it expands the existing knowledge base concerning the use of EEG as a tool for the detection of concealed information. This was done by examining whether a spectral indicator of deception exists. PDD tools used in the detection of deception assume that changes in physiological reactions indicate deception. However, physiological reactions can be influenced by a number of cognitive, motor, and emotional factors simultaneously (e.g. stress, mood effects). Thus, PDD tools such as the polygraph are not necessarily reliable indicators of a dynamic cognitive process generated in the central nervous system. EEGs tend to be comparable measures of deception in certain settings vis-à-vis current PDD measures. However, the use of spectral EEG as a tool for the detection of deceit has not been examined.

The chief problem with detecting deceit is that deception is a conscious and intentional process under most circumstances. Therefore, deceit is controlled by the individual. Outside the laboratory, subjects can choose or not choose to cooperate with tools and examiners who detect deception. Therefore, a direct means of detecting concealed information is required to more accurately index deception. Although the detection of familiarity versus nonfamiliarity of crime related information is not also a direct measure of deceit, the use of EEG to detect familiarity of stimuli is a modest improvement over current PDD measures because it indexes the source of the concealed knowledge base.

The purpose of the current study is to examine possible spectral indicators of deception vs. nondeception in the context of a mock crime. Possible spectral indicators of deception are frequency, amplitude, and electrode location. In the present study, there is some reasonable expectation that beta waves might index deception since they reflect mental processing during conscious states (Andreassi, 1989).

Presently, a mock crime was examined in which half of the subjects committed an act of espionage. The remaining half performed a scenario involving an errand not related to the espionage scenario and that did not contain any deceptive manipulations. However, all participants were examined concerning the espionage case. Thus, the espionage group was guilty of the crime in question while the errand group did not have any knowledge of the crime. The

espionage group was instructed to attempt to deceive the examiner while the errand group was instructed to be truthful. Examiners involved in detecting deception presented themselves as not having any knowledge of whether subjects were deceptive or nondeceptive and all subjects were directed by their trainer to withhold such information from the examiner.

Hypotheses

The principal concerns of this thesis are the EEG differences between deceptive and nondeceptive processing to crime relevant and irrelevant stimuli. Therefore, the main hypothesis is that differences should appear between relevant and irrelevant spectral EEG responses as well as for behavioral responses. Relevant responses are related to the particular scenario that a subject performs while irrelevant responses are related to the scenario that a subject does not perform. Also, there should be detectable differences between those subjects who participate in the mock crime, and those who do not. These differences should exist because the experimental subjects (i.e., those who commit the mock crime) are directed to lie.

A secondary concern in this thesis is to examine the behavioral and EEG differences between personally familiar words and foils (novel words), and whether these two differ from the irrelevant words from the two scenarios for each respective group. Since both personally familiar and foil words are not instrumental with regard to enacting either scenario, or in the directed lying, these conditions should elicit similar behavioral and EEG responses from both subject groups.

Method

Participants

Twenty participants were solicited from the local university community. They ranged in age from 17-26 years ($\underline{M} = 21.15$). Inclusion criteria for subject selection included right handedness, English as a first language, normal or corrected to normal vision, no history of neurological disorders, no history of learning disabilities, and no prior experience in a mock crime scenario or with lie detectors. Subjects were evenly divided, but randomly assigned, into an experimental group or a control group. The experimental group consisted of 10 subjects who enacted a mock crime involving espionage. The control group consisted of 10 subjects who performed a scenario involving an errand that did not contain any deceptive manipulations. Descriptive statistics indicated that individual characteristics (e.g. age, gender) were similar for both groups. Participants received extra-course credit for their participation in the study.

Apparatus for Spectral EEG Data

Subjects were fitted with a stretch forming electrode cap (Electro-Cap, International) imbedded with seven EEG tin electrodes. The recording sites included the International 10/20 system locations Fz, Cz and Pz at the midline and F7, F8, T3, and T4 sagittal to the midline. An additional electrode used for eye-artifact rejection was placed below the left eye. All electrode impedances were below 5 Kohms and variances between the reference electrodes on the mastoids were no more than 10 %.

EEG amplification filter constants were set at 0.1 and 30 Hz. This prevents the aliasing of brain and muscle artifact at frequencies beyond the cutoff. EEG was recorded at a net sampling rate of 800 times per second and digitized using the WinDaq software provided by DataQ Instruments, Inc.. Individualized artifact rejection thresholds were calibrated so that any trials containing eye blinks or excessive horizontal eye movement were rejected prior to analysis. Trials which passed artifact rejection criteria were sorted by trial-type condition. For every subject, three randomly selected artifact-free two second epochs for each condition underwent a Hamming window tapering and FFT analysis. The FFT yielded plots of power for each subject in each condition and for each electrode site. Frequency and amplitude data were recorded in reference to peak and trough amplitudes within the beta band (13 - 30 Hz). These three data for each subject, condition, and electrode site were averaged together and analyzed using an Analysis of Variance (ANOVA) procedure.

Apparatus for Behavioral Data

Behavioral data were collected by instructing subjects to press either a yes or no button on a computer keyboard as a function of the familiarity of the stimulus. A personal computer collected the response time in milliseconds and accuracy for each trial. These were analyzed offline and submitted to separate ANOVAs.

Stimuli

Stimuli consisted of 120 words presented in two-second intervals on a standard computer monitor. The stimuli were displaced approximately one degree of visual angle to the left and right of the center screen. Word categories included 30 words relating to the espionage scenario, 30 words relating to the errand scenario, 30 personally familiar words (relating only to the subject's personal preferences and derived from a checklist), and 30 foil words (words not related to the subject or any scenario). All words were randomly placed in a serial order that remained consistent for every subject. A verbal questionnaire was used to gather familiar words from each subject (see Appendix A). The questionnaire consisted of 30 distinct questions used to gather words personally related to the subject. Individual answers were not allowed to be more than two words in length. If an answer was the same as an item in a scenario or a previous answer, then the subject was asked to give an alternative response.

Procedures

When subjects arrived at the laboratory, the general objectives of the study and the presentation and recording procedures were explained to them. They were asked to endorse informed consent forms approved by the Institutional Review Board for this project. Each subject individually participated in the experiment by enacting a scenario on the first day and then performing a computerized task on the second day during their EEG exam.

Day 1

The experimental (espionage) group was given a key and told they needed to proceed to another location in a nearby building, enter by the side door, walk down a corridor, locate the correct room, and then enter the room while making sure that no person was in the room prior to entrance. Once in the room, subjects proceeded to a set of locked file drawers said to contain various blueprints of objects (missile diagrams and schematics). They unlocked the file drawer,

located and removed any documents or drawings relating to the spacecraft, photographed them with a small pocket camera given to them by the trainer, returned the documents to their correct folders, turned off the lights in the room, and made certain that the door was locked when they left. From that location, they exited the building the same way that they entered. As subjects exited the corridor, they encountered another confederate, posing as one of the janitors, who asked them casually why they were in the building after-hours. Subjects were coached not to reveal to anyone what they were doing, or where they were going. (Any subjects who did were ejected from the study because they were more likely to have violated other aspects of their instructions as well.) From the building, subjects proceeded to the park located across the street, and waited by the pond for a man wearing a black baseball cap with a soccer ball emblem. They approached the man in the black cap and briefly and quietly made a verbal exchange that indicated their identities. The man then took possession of the camera and gave the subject a sealed envelope containing a note. Subjects then returned to the laboratory for a debriefing with the trainer, producing the note as evidence that they completed the scenario.

The control (errand) group was given a pen, paper sack, and piece of paper, and were told to enter the library using the north entrance. Once in the library, subjects walked to an elevator located in the center of the building and went to the third floor. Subjects then walked out into the third floor and proceeded to find a pre-specified journal and book. Subjects opened the journal and wrote down the title of an article written by a specific author and a specific chapter title to a book. While the subjects were finding the journal and book, they encountered a confederate, who, after making a prespecified verbal exchange, gave each subject a disk which they placed in the paper sack. Once the subjects finished writing down the article and chapter titles on the piece of paper, they placed the pen and paper in the paper sack along with the disk. Subjects exited the library the same way they entered it and stopped to staple the sack twice on their way out. (Any subjects who did not staple the paper sack twice were ejected from the study because they were more likely to have violated other aspects of their instructions as well.) After leaving the library, subjects proceeded to the clock tower where they approached a man in a blue shirt holding a basketball and briefly and quietly made a verbal exchange that indicated their identities. The man then took possession of the paper sack and gave that subject a backpack. Subjects then returned to the laboratory for a debriefing with the trainer, producing the backpack as evidence that they completed the scenario.

The debriefing for all subjects involved the same individual who initially trained them for the scenario, and covered the main events, i.e., which documents were actually photographed for experimental subjects or which titles were actually written down for Controls. This procedure ensured that the important times, places, people, objects, and sequence of events were experienced by the subject, thereby becoming part of their knowledge base. Subjects were then told that they would be connected to a lie detection device the following day by an examiner who did not know which scenario they had conducted. All subjects were told not to verbally discuss the previously performed scenario with the examiner the following day. The errand subjects were told to be truthful about scenario related information in the experiment the next day, while the espionage subjects were told to conceal information about information related to their scenario. This was done by responding "no" to espionage-related words.

Day 2

Interactions between participants and the examiner were scripted in order to minimize potential verbal confounds between groups. Also, subjects watched a comedy video during electrode placement and did not have face-to-face contact with the examiner during the computer task in order to decrease possible nonverbal biases. All subjects were fitted with a stretch forming electrode cap. Subjects were then seated in a comfortable recording chair approximately three feet from a 15-inch color monitor attached to the stimulus computer. The stimulus computer was also linked to the EEG recording system for the purpose of triggering the digitizer. EEG signals were continuously digitized and event triggers were placed on the EEG referenced to stimulus onset. A two-button keyboard was given to subjects who then received instructions to enter manual responses concerning the familiarity of each target stimulus. The index finger from each hand corresponded to one of the two response buttons, and a key's function as to familiarity or unfamiliarity was counterbalanced across groups. A stimulus set consisting of 120 single word items was presented, one word at a time, each for a duration of two seconds. Each word was either relevant or irrelevant to the subject's enacted scenario. For instance, the words related to the espionage scenario were considered relevant for experimental subjects, while words related to the errand scenario, personally familiar words, and foils were considered irrelevant. For control subjects, words related to the errand scenario were considered relevant while words related to the espionage scenario, personally familiar words, and foils were considered irrelevant. The "personally familiar" items were drawn from the questionnaire given the previous day. The items in this category, therefore, were specific knowledge provided by the subject. Subjects were given a practice run on Day 1 to insure that they understood what the trial sequence would look like the following day. During the practice run, experimental subjects were trained to "fool" the examiner on Day 2 by responding unfamiliar to the espionage stimuli (an inaccurate response) but respond accurately to all other stimulus types. However, control subjects were trained to respond accurately to all stimuli. All subjects received the same sequence of randomized stimuli with their own personally familiar words inserted at the appropriate locations in the serial list.

Results

Appendix A list tables corresponding to all main effects and interactions for each ANOVA performed.

Behavioral Analyses

The behavioral data were analyzed using a 2 X 4 ANOVA design for two groups (experimental, control) and four word categories (espionage, errand, personally familiar, foil) with repeated measures on the latter variable. This model was applied to reaction time as well as response accuracy data.

Results of reaction time data did not reveal any significant main effects. However, a significant interaction effect of Group by stimuli was found for reaction time data $F\ (3,54) = 8.29$, $p < .001$ with milliseconds being the dependent variable (see Figure 1). Post-hoc pair-wise analysis indicated that the experimental group had faster reaction times to all stimulus types ($p < .05$) except for personally familiar items for which no difference between groups was found.

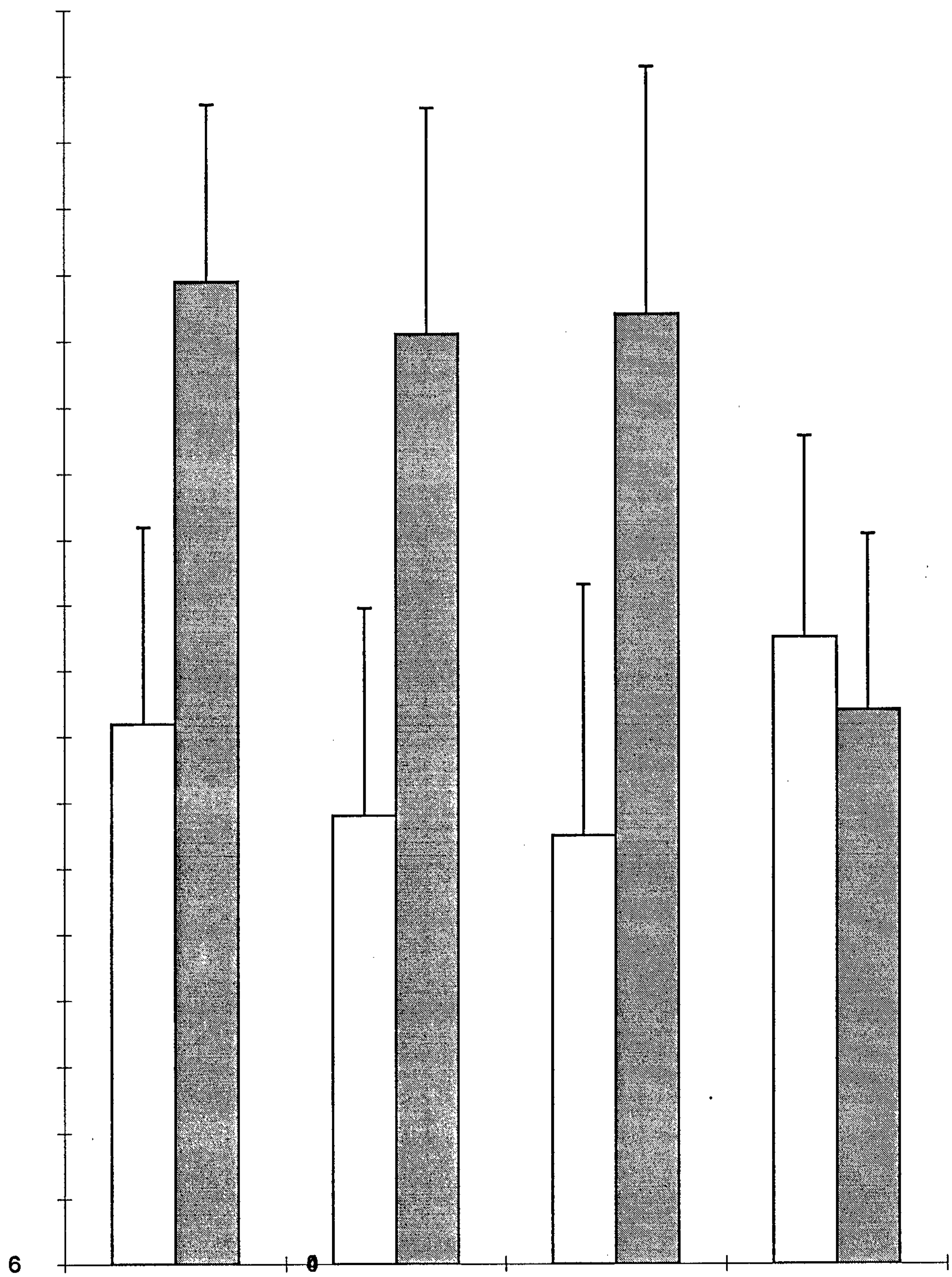

Figure 1. Effect of group by stimuli. Error bars represent one standard error of the mean.

Results for response accuracy data revealed a significant main effect of group $F(1, 18) = 24.47$, $p < .001$ where deceptive subjects responded more accurately (93 % accuracy rate) than innocents subjects (80 % accuracy rate). However, no main effects for stimuli were found. A significant interaction effect of Group by stimuli was found $F(3, 54) = 9.07$, $p < .001$. Post-hoc pair-wise comparisons indicated that the experimental group responded more accurately to all stimulus ($p < .05$) categories except for personally familiar items.

Spectral EEG Analyses

A 2 X 4 X 3 ANOVA, having a group factor (deceptive versus nondeceptive), four repeated measures concerning stimuli (espionage, errand, personally familiar, foil), and three repeated measures for electrode location (Fz, Cz, Pz) was applied to the mid-line spectral EEG data. This model was separately applied to four dependent variables: high peak frequency, peak amplitude, low peak frequency, and trough amplitude. For amplitude, the concepts peak and trough refer to the magnitude of the Fourier Transform (FFT). Frequency is distinguished by high or low peaks referring to peak or trough amplitudes in the FFT respectively.

No significant results were found for peak amplitude, low peak (trough) frequency, or trough amplitude. However, a significant interaction effect of Group by midline $F(2, 36) = 5.69$, $p < .007$ was found for high peak frequency data (see Figure 2). Post-hoc pair-wise comparisons found that Experimentals differed from controls at electrode sites Fz and Pz, but not at Cz.

A 2 X 4 X 2 X 2 ANOVA, having a group factor (deceptive vs. nondeceptive), four repeated measures concerning trial-type (espionage, errand, personally familiar, foil), repeated measures concerning electrode location (anterior vs. posterior), and repeated measures concerning hemisphere (left vs. right), was applied to the sagittal spectral EEG data. This model was separately applied to all four dependent variables: high peak frequency, peak amplitude, low peak frequency, and trough amplitude.

No significant effects were found with high peak frequency data and trough amplitude data. No significant main effects were found with trough amplitude and peak amplitude data. However, a significant four-way interaction of electrode by stimulus by hemisphere by group $F(3, 54) = 4.04$, $p = .012$ was found for trough amplitude. Due to the sheer size of a four-way interaction (difficulty in making comparisons and increased likeliness of Type I error), the effect was not explored further. For peak amplitude data, a significant interaction of electrode by hemisphere $F(1,18) = 4.28$, $p = .053$ was found. The left hemisphere temporal site had a higher peak amplitude than the left hemisphere frontal site.

No significant main effects were found for low peak frequency data. However, several significant interaction effects were found. A significant three-way interaction of group by stimulus by hemisphere $F(3,54) = 2.99$, $p < .04$ was found (see Figure 3). Post-hoc analysis found that experimental subjects differed from control subjects on personally familiar items in the right hemisphere and with errand words in the left hemisphere. Control subjects had frequency troughs at a higher frequency than experimental subjects for both familiar items recorded in the right hemisphere and errand words in the left hemisphere. A significant interaction of group by electrode $F(1,18) = 14.48$, $p < .001$ was also found for low peak frequency data. Experimentals

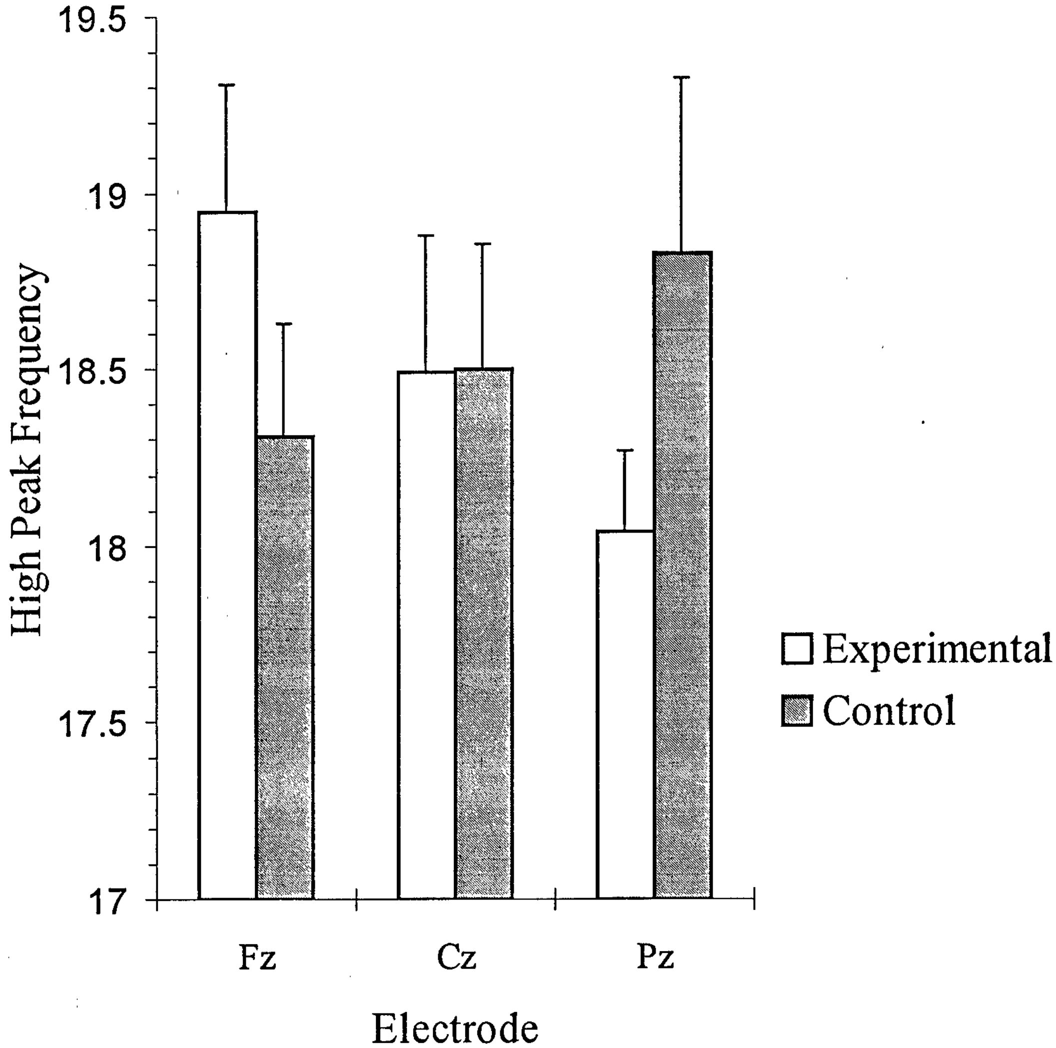

Figure 2. Effect of group by midline sites for high peak frequency. Error bars represent one standard error of the mean.

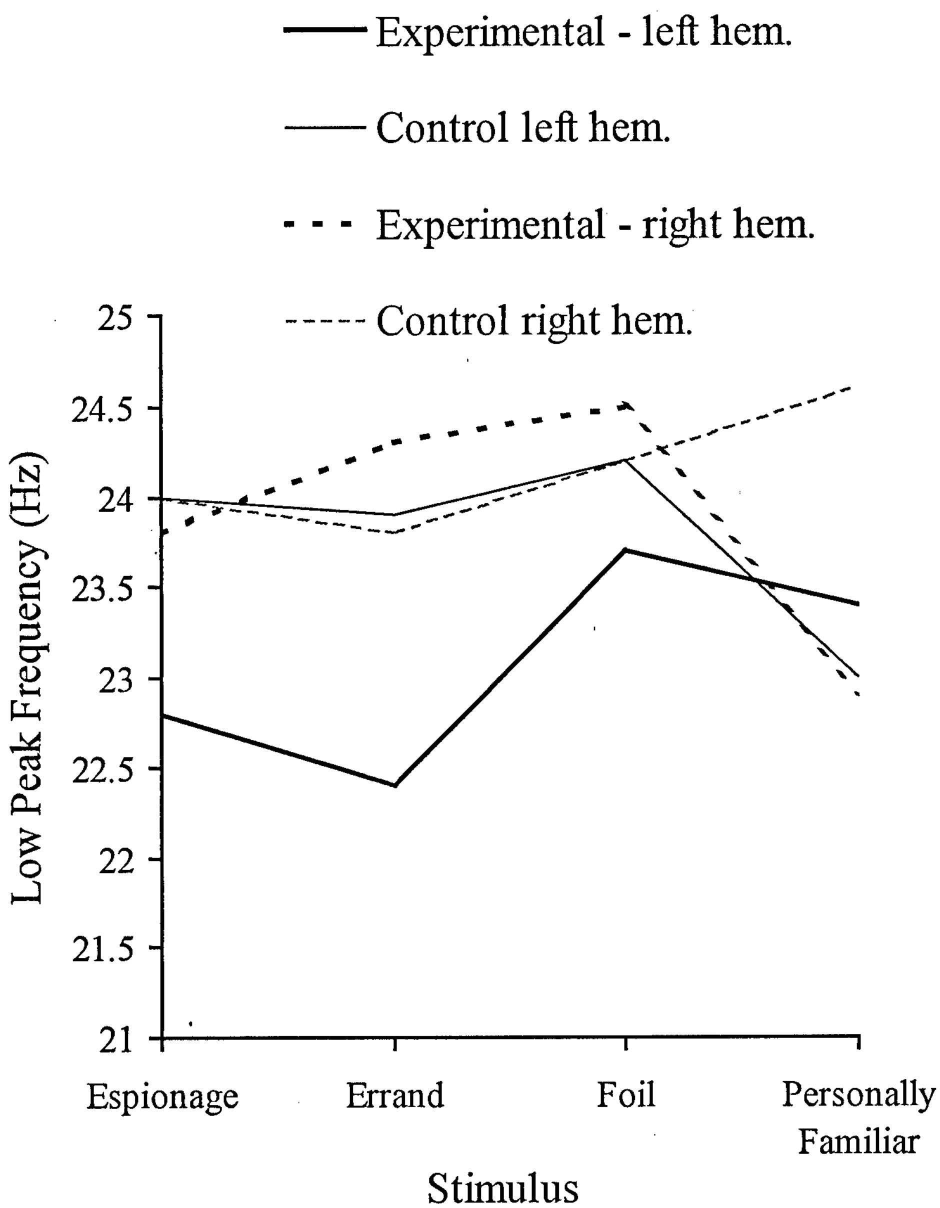

Figure 3. Effect of group by stimulus by hemisphere for low peak frequency.

had lower peak frequencies at temporal sites than controls while controls had lower peak frequencies at frontal sites. Last, a significant interaction of stimulus by electrode $F(3,54) = 3.43$, $p < .023$ was found. Post-hoc pair-wise comparisons revealed that only errand stimuli differed in frontal versus temporal trough peak frequency.

Discussion

Results of this experiment suggest that both behavioral and spectral differences between deceptive and non-deceptive subjects exist. Deceptive subjects process stimuli differently from non-deceptive subjects. However, this difference does not appear to be a function of relevance of, or familiarity with, a stimulus. Instead, group differences occurred with respect to whether the subject was directed to lie or not. This is consistent with behavioral findings in Locker and Pratarelli (1997) in which experimental subjects performed differently than control subjects and informed subjects in all stimulus type conditions. In their experiment, however, Experimentals were slower in all conditions than Controls.

Behavioral Findings

In contrast to Locker and Pratarelli (1997), deceptive subjects in the present experiment were faster and more accurate than nondeceptive subjects at responding to all stimuli except for personally familiar words (Figure 1). The results indicated that the difference in response accuracy, however, can be explained as a main effect of Group. Previous research has often found a trade-off between response time and response accuracy (cf., Dickman & Meyer, 1988; Locker & Pratarelli, 1997). Subjects who respond slower tend to be more accurate, and vice-versa, because being more accurate requires more controlled effort. This controlled effort requires more cognitive processing revealed by slower reaction times (Kihlstrom, 1987). Locker and Pratarelli (1997) found that deceptive subjects responded slower than non-deceptive subjects because the act of concealing information required more conscious and controlled effort than nonconcealment. The present results are consistent with these findings in that differences were found between deceptive and nondeceptive subjects. However, the present findings differ in that deceptive subjects were faster and more accurate in responding to stimuli. This departure from previous findings may be due in part to (1) motivation, and (2) to subtle differences in task demands.

Motivation may cause experimental subjects in the present study to respond quicker and more accurately to all stimuli except for personally familiar items. The supposition that motivation differentially affects deceptive versus non-deceptive subjects may center on the notion that deceiving with impunity is intrinsically enjoyable. Moreover, all subjects were motivated to participate in the present experiment by being offered extra-course credit for each hour of participation and by the nature of the study. The underlying logic is that deceptive subjects may have greater motivation or self-investment in the act of potentially deceiving the examiner while the non-deceptive subjects had little or none at all. Previous studies that have examined deceit have tried to equate motivational levels of deceptive and non-deceptive subjects either by offering specific incentives for performance, such as monetary rewards, or by utilizing a design that allows subjects to choose whether to be deceptive or nondeceptive (Elaad & Ben-Shakhar, 1989; Furedy & Ben-Shakhar, 1991; Locker & Pratarelli, 1997). The use of monetary rewards assumes that motivation derived will overcome intrinsic motivation, and thus equate deceptive and non-

deceptive subjects. Alternatively, the use of a design that allows subjects to choose whether to deceive or not assumes that all subjects will be equally intrinsically motivated because each participant would receive some degree of self gratification and self-efficacy from the choice made (Bandura, 1977). However, these two approaches used to control for motivation may lack ecological validity because consequences often seen when an individual submits to a lie-detection test are absent. Nonetheless, future research needs to clarify whether the current behavioral results reflect differences in intrinsic motivation, and whether that motivation equates with that seen in genuine deception.

In terms of task demands, another reason the present deceptive subjects performed, as a group, similar to Locker and Pratarelli's (1997) subjects, but faster instead of slower, is less ecological validity. In Locker and Pratarelli, when subjects self selected into the deception group they believed they were both fooling the investigator, and their integrity would be questioned if they were discovered, i.e., it was learned that they had taken a list of words to be presented on the next day's test from a confederate. From these subjects' perspective, their self-efficacy was principally determined by their investment in not disclosing that they had taken a single piece of paper for their own personal gain. In the present study, this personal self-investment and loss of integrity through discovery is significantly diminished because (1) subjects worked together with their trainer to fool the examiner, and (2) there was no potential loss of integrity if their deception was discovered because they were told to do so in the context of the experiment. That is, the deception had been, in effect, legitimized and operationalized in the task demands. Thus, Locker and Pratarelli's subjects would have had to slow down to increase their accuracy in order to maintain their deception while the present subjects could afford to speed up.

The finding that group differences occurred for all stimulus types except personally familiar words might be better explained in that personally familiar words are self generated while the other stimulus types were not. Recall that personally familiar words were gathered from each subjects' prior experiences independent of the experiment. But, the relevant scenario items were experienced by subjects only within the confines of the experiment. Thus, self generated items may include *ego involvement* where the other stimuli did not (M. E. Pratarelli & D. Krapohl, personal communication, April 16, 1999). In this sense, ego involvement is a psychological construct that is implicitly related to one's sense of self, efficacy, and personal investment (Bandura, 1977). Bandura and others (e.g., Pratarelli & McIntyre, 1994) have shown that as the subject's sense of personal investment and ego involvement increased, so did their individual or group performance. Note, however, that the use of the term "ego" is here, a matter of convenience, rather than an endorsement or inclusion of the various definitions and issues raised by Freud's psychodynamic theory. Personally familiar words may not have differentiated deceptive from nondeceptive subjects because both groups had equal ego involvement whereas the other stimulus types are not affected by this construct.

<u>Spectral Findings</u>

The finding that deceptive subjects process stimuli different from nondeceptive subjects is shown by the midline effect of Group by electrode for high peak frequency data, illustrated in Figure 2. This effect is interesting in that high peak frequency may index the level of Beta activity in anterior versus posterior regions of the brain. Recall that Beta activity reflects more processing

of the cognitive variety. Generally, it is axiomatic in neuroscience that the posterior portion of the cortex is dedicated to sensory and perceptual processing of stimuli from the environment, while the anterior portion is dedicated to the organism's motor behavior, thought, and responses to the environment. The act of deception recruits all three of the latter processes. Thus, the main effect of Group is interesting in that the deceptive subjects showed a higher peak frequency in the Beta bandwidth at Fz, an anterior site, than nondeceptive subjects, while the opposite occurred at Pz, a posterior site. Moreover, this effect was extracted from data pooled across all four word conditions. This would indicate that deception may be indexed as a state rather than an effect attached to deceptive stimuli.

Using the explanation discussed earlier regarding personal investment, integrity, self-efficacy, and ecological validity as construed in the term "ego involvement", deception may be indexed by cortical activation in frontal brain areas that would be concerned with such matters of the self. While this is merely drawing the causal argument from the observed correspondence between frontal EEG activity and the inferred location of the cortical substrates for "ego", self, or thought in general, it raises an important testable hypothesis for future research to address. In support of this argument, it is important to note that the preponderance of brain-imaging research, clinical neuropsychological evidence, and research in the psychopathology of Schizophrenic and affective disorders have localized thought-related brain electrical activity to the frontal lobes (Gershon & Rieder, 1993).

A similar effect of anterior to posterior processing in lateral sites is seen with the Group by electrode effect with low peak frequency data. As with high peak frequency, low peak frequency may similarly index deception. Again, these effects seem to indicate that experimental subjects are concentrating on an appropriate response while control subjects are more concentrated on the stimulus itself. In addition, it is important to note that if peak-to-peak amplitude at each frequency band had been calculated and used as a dependent variable, it would have been equally sensitive to deception. Although not always used, peak-to-peak power or voltage has been a dependent variable in previous research.

Subjects did not process stimuli differently based on relevance of the stimulus. If relevance to scenarios were to differentiate deceptive from non-deceptive subjects, then group differences would be expected for stimuli that are relevant for one group but not the other, i.e., espionage vs. errand. The three-way interaction of Group by stimulus by hemisphere for low peak frequency data indicates that group differences exist for errand words in the left hemisphere, but no differences were found for errand words in the right hemisphere (Figure 3). There were no differences for espionage words in either hemisphere. Thus, relevance to scenario was not found in those two conditions for either group of subjects.

As related earlier, group differences illustrated in Figure 2 do not appear to be a function of the familiarity of the stimulus. Although the Group by stimulus by hemisphere effect for low peak frequency data reveals that deceptives differed from nondeceptives on personally familiar words in the right hemisphere, these results do not correspond to the familiarity of a stimulus because both deceptives and nondeceptives were familiar with personally familiar items and unfamiliar with foil items and irrelevant items from the scenario they did not participate in.

Nonetheless, the observed difference between groups on personally familiar items is not readily interpretable, and in fact, is contrary to what was predicted on theory alone; this result awaits further study.

Several significant spectral EEG findings were found that are unrelated to any hypotheses of this study. The effect of electrode by hemisphere for peak amplitude data where the left temporal site showed a higher peak amplitude than the left frontal site is not clearly interpretable. However, this effect could be due to differences in language processing because the temporal site may better index language processing than the frontal site. An interpretation of the stimulus by electrode effect for trough peak frequency is also unclear. No logical reason why only errand stimuli would differ in relation to frontal versus temporal sites has been determined. Therefore in lieu of an explanation, this finding might be reconciled as a Type I error.

Implications & Future Research

Behaviorally, intrinsic motivation appears to account for the differences between groups, i.e., between deceptive and nondeceptive subjects. However, this interpretation does not explain why group differences were not found for personally familiar words in both reaction time and response accuracy. Future research should examine motivational attributes of deception more closely in order to determine the extent to which behavioral indices can discriminate between deceptive and nondeceptive subjects. Since deception is predominantly a conscious process, deceptive subjects may require more controlled cognitive processing in order to intentionally respond falsely to stimuli (Locker & Pratarelli, 1997). However, if motivation alone can account for differences between behavioral measures, then this finding may also reveal just how easily such indices can be consciously controlled. A concern in lie-detection is whether an individual could potentially 'beat' the Examiner using a consciously controlled state of mind (Bashore & Rapp, 1993). If intrinsic motivation can indeed account for differences between deceptive and nondeceptive subjects, then the extent to which behavioral data can accurately predict whether the subject is indeed guilty or innocent of deceiving is questionable because of the ease with which subjects can consciously control such behaviors.

It is important to note a dearth of research concerning intrinsic motivation and its effects on deception. This does not facilitate exploring the implications of the behavioral findings. Intrinsic motivation has been found to be a function of many cognitive constructs (i.e., interest, effort, excitement, arousal, intention, etc.) all of which are related to individual differences. As a minimum, future research should include a survey given to subjects at the end of the experiment to determine whether motivation is a function of deception or individual differences. This has been implemented in our replication study.

Although the behavioral results might be related to intrinsic motivation, the spectral EEG results are less likely to be a function of motivation because Beta frequencies reflect higher cognitive processing (Andreassi, 1989). However, Alpha and Delta activity that reflect relaxation and underarousal respectively may indicate whether motivational differences exist because attention is often seen behaviorally as alertness as in intentional learning (Kosslyn & Koenig, 1992). Thus, future research should examine these frequency bands as possible indices of motivational differences.

The most intriguing finding at present is the spectral difference found between deceptive and non-deceptive subjects that appears to be a function of perceptual versus response processing. This finding is also important because it differs from differences found in previous deception research. PDD, in examining deceptive versus nondeceptive-related SANS activity, has not found a direct index of deception (Ford, 1995). Previous research utilizing EEGs have the theoretical advantage of measuring deception more accurately because they index the CNS, but have only been able to discriminate between deceptive and nondeceptive subjects based on word familiarity or context violation. However, the current findings not only measure CNS activity, but they are also not a function of the relevance or familiarity of stimuli. Although the familiarity of stimuli has been found to be a reliable indicator of deception, often unavailable details of the act in question are required to utilize this technique (i.e., the GKT vis-à-vis Farwell & Donchin, 1991; Rosenfeld et al., 1988). However, group differences found between anterior and posterior regions of the brain may be a more valid and reliable measure of deceit because these effects occurred irrespective of stimulus type. Thus, this finding may be a tenuous indicator of concealed information that has previously eluded lie-detection researchers. Replications need to be conducted to insure that deceptive and nondeceptive subjects do in fact differ in respect to anterior-posterior processing. Second, statistical discrimination techniques should be employed to determine whether this difference can differentiate deceptive from nondeceptive subjects on an individual basis. Third, future research needs to examine whether this measure is sensitive to a conscious attempt to trick the examiner as in the use of physical and mental countermeasures.

Although the implications of these results have been directed toward distinguishing deceit from nondeceit, they provide several insights into our conceptual understanding of deception. Specifically, deception seems to differ from nondeception in relation to anterior versus posterior processing. However, specific interpretations concerning spatial differences are premature because many techniques such as topographic measures of cortical activity provide better spatial resolution than spectral EEG. Thus, future research using tools that are more spatially detailed such as computerized topography, Laplacian derivation of EEG sources, functional magnetic resonance imaging, and positron emission tomography should be conducted to explain more precisely where deceptive processing differs from nondeceptive processing. The anterior-posterior differentiation may give comparative clues as to how deception evolved. Researchers have increasingly used the act of deception as an indicator of complex mental processing when comparing humans to other primates (Greenberg, 1999). If deception does require the development of increased mental processing, then the ability to skillfully deceive may correspond to the enlargement of the frontal lobes, where conscious thought processes occur (Fischbach, 1992). A comparative approach to the development of deceptive behavior may be studied by examining differing types in relation to anterior-posterior processing.

In conclusion, this experiment has provided electrophysiological as well as behavioral evidence that deceit can be detected using CNS measures of cognitive processing. More importantly, the evidence suggests that the anterior versus posterior regions of the cortex may process deception and nondeception differentially. The findings are preliminary due to the exploratory nature of the study. Nonetheless, these findings suggest that spectral EEG can be used to further the understanding of lie detection, the nature of deception, and ultimately guilt.

Replication Experiment

The first experiment not only provided a compelling need to replicate the differential effect between deceivers and non-deceivers, but more importantly it yielded critical insights into the methodological protocol. Although this one-year exploratory project was focused on developing and conducting the initial pilot study reported as Experiment 1 above, the remainder of funds were applied to a second Experiment (2). In an effort to at least partially replicate the effects found in the initial experiment, and because we experimented with different methods for decomposing the EEG spectra, a second series of subjects (N = 20) were recruited for participation using the same behavioral mock crime and errand task protocols described earlier.

Procedurally, Experiment 2 differed from Experiment 1 in that subjects were offered $10 for their participation, and an additional $20 if they were successful in fooling the Examiner. (Because of ethical considerations, all subjects were ultimately told during debriefing that the Examiner was unable to make a decision regarding which of the two scenarios they had participated in. Therefore, all 20 subjects received the $20 bonus.) The modification of subject incentive from extra course credit to monetary reward arguably could affect the results, but only minimally since the subjects in both groups received the same instructions focused on "beating the Examiner."

A second procedural departure involved subjects being presented stimulus items in a block format. In Experiment 1, the presentation of stimuli were randomized, thus subjects did not have prior knowledge as to any particular order of stimulus types. However, Experiment 2 utilized a block stimulus presentation in which all stimuli in their particular category were presented together. This modification allowed for more concise stimulus type differentiation during EEG analysis. Another biproduct of this modification was that subjects were more inclined to enter into a state wherein their intentions within the entire block was either deceptive or nondeceptive. Since the stimuli were presented in block format, subjects already knew what the next stimulus would be. Thus, reaction time is no longer a valid metric of processing speed or integrity, but merely a ritualized behavior subjects perform in order to keep them attending to the words to extract the EEG effects. Motivationally, we countered this effect by stressing to subjects they needed to be vigilant in monitoring the stimuli to make sure each was in fact from the category requiring its corresponding response. Also, instructions to the subjects were modified to include a statement warning that in order to receive their money, a correct response had to be recorded for each stimulus within the block.

Subject's were also administered a brief four-question exit survey in the hopes of determining the source of their motivation and interest in participating. The survey asked subjects to rate on a scale of 1-7 how interesting, effortful, challenging, and how enjoyable they found their participation in the study.

Another significant methodological departure from Experiment 1 concerns the electrode array. In order to maintain parity with Experiment 1, the midline sites were retained with a monopolar configuration. However, on separate amplifier channels the midline sites each became

reference locations for bilateral bipolar configurations. This was done in order to examine any possible hemispheric asymmetries that might exist. Lateral sites T3/T4 and T5/T6 were also recorded as both monopolar and bipolar configurations. The six bipolar sites recorded were: F7-Fz; F8-Fz; T3-Cz; T4-Cz; T5-Pz; and T6-Pz. This configuration was also considered because it would permit a more valid analysis of hemispheric asymmetries at a later date. Finally the analysis protocol was also modified. First, the sampling rate for the 12 channels of EEG and one eye electrode was increased to 2800Hz to accommodate decomposition of higher frequencies above 30Hz. This was done in order to (1) replicate the data collection for Beta I frequencies between 13-30Hz, and (2) examine any possible effects in the Beta II bandwidth between 30-50Hz. Thus, there were 56 individual sampling points between 13 and 50.3Hz available for off-line analysis. Of particular interest was the 40Hz frequency zone. This high frequency band has been implicated as a metric of "effortful" conscious-controlled processing in which "focused" arousal can be measured (Loring & Sheer, 1984; Mattson, Sheer, & Fletcher, 1992; Sheer, 1976; 1984). Sheer has argued that a "40Hz rhythm" is manifest by the shifting of EEG activity related to instances of high concentration (Loring & Sheer, 1984; p.34). Therefore, our working logic for Experiment 2 was that real-life deception outside the laboratory setting might be analogous to the concentration generated during directed-lying. The directed lying was motivated by the $20 bonus incentive and complemented by an amount of ego involvement attributed to "beating the Examiner." Moreover, the incentive is argued to be non-identical, but comparable to the personal incentive of avoiding detection and possible indictment for a criminal behavior.

Secondly, the EEG data were subjected to a Discrete Fourier Transform (DFT) rather than the conventional FFT because it facilitated temporally narrowing the analysis window so that a preponderance of stimulus (event-related) processing, and less of the unrelated pre and post stimulus processing activity was actually analyzed. The effect ultimately improves the signal to noise ratio. A smoothing function was also applied to the DFT using a five-point integration. This improved the ease of identifying and analyzing areas along the DFT spectral wave where differences are expected. In addition, three sample DFTs corresponding to three separate words from each category were analyzed with this procedure. These three were used to compute an average DFT wave, which was later used for the statistical analyses. This provided an additional level of data reduction that also helped improve the signal to noise ratio. In addition, because the smoothing function and the signal averaging routines improved the signal strength, there was no longer a need to visually inspect the FFT and isolate the peak within the analysis window of interest. Instead, all frequencies between 13 and 50 Hz were subjected to statistical analysis. This also improved the scope of the analysis by adding degrees of freedom where psychophysiological effects might appear.

Results of Experiment 2

At the time of this report, the averaged DFT waveform data for the midline sites were the only ones available. These were submitted to an ANOVA using the model Group (2) by stimulus condition (4) by Electrode (4) by Frequency (20). In contrast to the analysis in Experiment 1, 20 separate time samples between 20 and 40 Hz were analyzed simultaneously rather than preselecting the individual peaks or valleys in the target area between 13 and 30 Hz. Therefore, the Electrode by Group by Frequency three-way interaction might be expected to reveal

comparable effects to Experiment 1. There was no significant effect, however. Instead, there was *a main effect of Frequency (*p* < *.0005)*, and a significant interaction between Frequency and Group (*p* < *.028)*. There were no other interaction effects that involved Group differences. Table 1 lists the main effects and interactions for all *between* and *within* subject factors in the 4-way ANOVA.

Table 1
Effects of the 4-way ANOVA for Replication Data

Source	DF	F	Probability
Electrode	3	1.83	.092 **
Stimulus	3	2.78	.050 *
Frequency	19	201.2	.000 *
Group	1	.409	.530
Electrode x Group	3	.137	.937
Stimulus x Group	3	.179	.910
Frequency x Group	19	1.74	.028 *
Electrode x Stimulus	9	1.52	.144 **
Electrode x Frequency	57	2.81	.000 *
Stimulus x Frequency	57	1.07	.337
Electrode x Stimulus x Group	9	.757	.656
Electrode x Frequency x Group	57	.647	.981
Stimulus x Frequency x Group	57	1.04	.394
Electrode x Stimulus x Frequency	171	1.27	.012 *
Electrode x Stimulus x Frequency x Group	171	.780	.983

Note. *p < .05. **Marginal effects requiring further scrutiny.

One important consistency with the results of Experiment 1 is that a contiguous string of significant effects from 23-26 Hz (*p* < *.013; 023; 028*, respectively) did reveal Group differences. These are in close proximity to the frequency effects reported in Experiment 1 in the vicinity of 20Hz. The important disparity between these and Experiment 1 effects is that when anterior versus posterior recording sites were considered in the analysis (Electrode), the Group effect disappeared. Electrode was significant in the Electrode by Frequency two-way interaction (*p* < *.0005*), and in the Electrode by Word by Frequency three-way interaction (*p* < *.012*).

The questionnaire data were analyzed using a 2 X 2 X 4 ANOVA mixed design consisting of the following factors: group (deceptive versus nondeceptive), gender (males versus females), and four repeated measures concerning question type (enjoyment, challenge, interest, and effort). There were no significant main effects nor interactions concerning either group or gender. However, a significant main effect for question type was found ($p < .001$). Subjects stated that the study was enjoyable and interesting, but not challenging and did not require a lot of effort.

Discussion

Given that this ANOVA focused on the 20-40Hz frequencies, there is clearly some support for the Group effects found in Experiment 1. The quasi-replication of Experiment 1 was focused on improving the methodology, and thus should not be viewed as an ideal replication. Differences found in Experiment 2 could have been due to any number of possible modifications to the procedure, including the block versus randomized stimulus presentation format, subject motivation changes due to monetary incentives offered in Experiment 2, variability in the identification and selection process used to isolate peaks and valleys in Experiment 1, noise captured in the broader window of the FFT analysis that was more limited with the narrower DFT analysis. In addition, since the research team continued to improve its performance during subject training and data collection phases even into the replication experiment, it is also possible that refinement of the procedural aspects of the study may have contributed to differences between the results of Experiments 1 and 2. Nevertheless, it is important to note that in both Experiments, the spectral analyses were sensitive to Group differences. However, the notion that group effects may have occurred in respect to motivational or attentional differences instead of deception versus nondeception was not supported by the questionnaire data. Therefore, methodological issues notwithstanding, we conclude that the use of spectral EEGs demand further study, with a focus on determining which of several possible methodological constraints will optimize the determination and assignment of "deceptive" to individual examinees.

Further study in our laboratory is aimed at using the Experiment 2 data to extract the peaks and valleys using the same data reduction protocol employed in Experiment 1. Those and other results of the Experiment 2 analyses will be reported in a subsequent or supplemental report to DoDPI or in the public literature. More importantly, the fact that significant Group effects were found in the same high frequency Beta I band of the EEG in both Experiments, supports the initial contention and the thesis of this study that indeed, CNS activity analyzed as power spectral components can be used to make Group identifications of subjects in mock crime laboratory studies.

In addition to replicating Experiment 1 using randomized stimulus presentations, continued analysis of the data generated in Experiments 1 and 2 following the date of this report are focused (1) on discrete examination of the power spectral Beta II components between 40 and 50Hz, (2) Beta I frequencies between 13 and 20Hz not analyzed in the initial ANOVA, (3) more intense analysis of the data between 30 and 50 Hz for the purpose of examining the 40Hz rhythm effect described by Sheer for focused arousal, and (4) the corresponding analyses that will examine any laterality effects. The latter combined with the midline analyses will ultimately be used to refine a localization analysis. Finally, we anticipate using this same database to examine individual subjects with the expectation that such data will be subjected ultimately to discriminant analysis, a bootstrapping procedure, or a more appropriate prediction algorithm (see Appendix C). Additional projects already planned for these data also include regression analyses using the demographic data and survey information collected from each subject, e.g., the Machiavellian data.

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Appendix A

Verbal Questionnaire Related to Personally Familiar Words

Order	Question	Answer
1	Mother's first name	______________
2	Favorite color	______________
3	Type of vehicle you drive the most	______________
4	Favorite meal (breakfast, lunch, dinner)	______________
5	Favorite season	______________
6	Favorite food	______________
7	Favorite fruit	______________
8	Month born	______________
9	Favorite sibling or friend	______________
10	Favorite type of pet	______________
11	Name of the street that you live on	______________
12	Favorite type of drink	______________
13	Favorite type of music	______________
14	Favorite language	______________
15	Favorite number between zero and nine	______________
16	Favorite Sport	______________
17	Favorite Furniture	______________
18	Favorite smell	______________
19	Favorite mode of travel	______________
20	Favorite type of bread	______________
21	Favorite recreational/hobby activity	______________
22	Favorite time of day	______________
23	Favorite cloth	______________
24	Favorite type of game (board, cards)	______________
25	Favorite climate	______________
26	Favorite type of terrain	______________
27	Favorite type of place to visit	______________
28	Most positive part of your personality	______________
29	Type of person that you would like to be	______________
30	Type of career that you want to strive for	______________

Appendix B

Tables of Main Effects and Interactions

Effects of the 2-way ANOVA for Reaction Time Data

Source	DF	F	Probability
Stimulus	3	2.11	.109 **
Group	1	1.58	.225
Stimulus x Group	3	8.29	.001 *

* Significant at .05 or better.

** Marginal effects requiring further scrutiny.

Effects of the 2-way ANOVA for Response Accuracy Data

Source	DF	F	Probability	
Stimulus	3	0.55	.652	
Group	1	24.47	.001	*
Stimulus x Group	3	9.07	.001	*

* Significant at .05 or better.

** Marginal effects requiring further scrutiny.

Effects of the 4-way ANOVA for Midline High Peak Frequency Data

Source	DF	F	Probability	
Electrode	2	0.42	.662	
Stimulus	3	1.39	.256	
Group	1	0.01	.905	
Electrode x Group	2	5.69	.007	*
Stimulus x Group	3	0.30	.822	
Electrode x Stimulus	6	1.43	.210	
Electrode x Stimulus x Group	6	0.74	.616	

* Significant at .05 or better.

** Marginal effects requiring further scrutiny.

Effects of the 4-way ANOVA for Midline Peak Amplitude Data

Source	DF	F	Probability
Electrode	2	1.13	.334
Stimulus	3	1.50	.225
Group	1	1.06	.318
Electrode x Group	2	0.13	.879
Stimulus x Group	3	1.25	.299
Electrode x Stimulus	6	1.33	.249
Electrode x Stimulus x Group	6	0.36	.902

* Significant at .05 or better.

** Marginal effects requiring further scrutiny.

Effects for the 4-way ANOVA for Midline Low Peak Frequency Data

Source	DF	F	Probability	
Electrode	2	0.21	.813	
Stimulus	3	0.65	.584	
Group	1	2.42	.137	**
Electrode x Group	2	0.19	.830	
Stimulus x Group	3	0.04	.990	
Electrode x Stimulus	6	0.40	.879	
Electrode x Stimulus x Group	6	0.71	.639	

* Significant at .05 or better.

** Marginal effects requiring further scrutiny.

Effects of the 4-way ANOVA Midline Trough Amplitude Data

Source	DF	F	Probability	
Electrode	2	0.70	.501	
Stimulus	3	2.14	.106	**
Group	1	1.23	.281	
Electrode x Group	2	0.00	.995	
Stimulus x Group	3	1.00	.401	
Electrode x Stimulus	6	0.83	.547	
Electrode x Stimulus x Group	6	1.58	.159	

* Significant at .05 or better.

** Marginal effects requiring further scrutiny.

Effects of the 4-way ANOVA for Sagital High Peak Frequency Data

Source	DF	F	Probability	
Electrode	1	1.66	.214	
Stimulus	3	1.17	.330	
Hemisphere	1	2.57	.127	**
Group	1	0.04	.849	
Electrode x Group	1	0.97	.339	
Stimulus x Group	3	0.69	.561	
Hemisphere x Group	1	0.68	.420	
Electrode x Stimulus	3	1.16	.333	
Electrode x Hemisphere	1	0.96	.339	
Stimulus x Hemisphere	3	2.26	.092	**
Electrode x Stimulus x Group	3	0.11	.954	
Electrode x Hemisphere x Group	1	0.70	.414	
Stimulus x Hemisphere x Group	3	0.25	.862	
Electrode x Stimulus x Hemisphere	3	0.36	.780	
Electrode x Stimulus x Hemisphere x Group	3	1.61	.199	

* Significant at .05 or better.

** Marginal effects requiring further scrutiny.

Effects of the 4-way ANOVA for Sagital High Peak Amplitude Data

Source	DF	F	Probability	
Electrode	1	2.80	.111	**
Stimulus	3	1.85	.149	**
Hemisphere	1	1.09	.310	
Group	1	1.78	.199	
Electrode x Group	1	0.61	.444	
Stimulus x Group	3	.031	.818	
Hemisphere x Group	1	1.26	.277	
Electrode x Stimulus	3	2.21	.097	**
Electrode x Hemisphere	1	4.28	.053	**
Stimulus x Hemisphere	3	0.50	.686	
Electrode x Stimulus x Group	3	1.45	.238	
Electrode x Hemisphere x Group	1	0.44	.515	
Stimulus x Hemisphere x Group	3	1.35	.269	
Electrode x Stimulus x Hemisphere	3	0.32	.812	
Electrode x Stimulus x Hemisphere x Group	3	0.34	.796	

* Significant at .05 or better.

** Marginal effects requiring further scrutiny.

Effects of the 4-way ANOVA for Sagital Low Peak Frequency Data

Source	DF	F	Probability	
Electrode	1	1.21	.285	
Stimulus	3	1.77	.163	
Hemisphere	1	2.90	.106	**
Group	1	1.83	.193	
Electrode x Group	1	14.48	.001	*
Stimulus x Group	3	0.36	.784	
Hemisphere x Group	1	0.40	.534	
Electrode x Stimulus	3	3.43	.023	*
Electrode x Hemisphere	1	0.80	.382	
Stimulus x Hemisphere	3	0.15	.932	
Electrode x Stimulus x Group	3	0.68	.569	
Electrode x Hemisphere x Group	1	0.52	.481	
Stimulus x Hemisphere x Group	3	2.99	.039	*
Electrode x Stimulus x Hemisphere	3	0.17	.913	
Electrode x Stimulus x Hemisphere x Group	3	1.39	.255	

* Significant at .05 or better.

** Marginal effects requiring further scrutiny.

Effects of the 4-way ANOVA for Sagital Low Amplitude Data

Source	DF	F	Probability	
Electrode	1	1.97	.177	
Stimulus	3	1.73	.171	
Hemisphere	1	0.00	.960	
Group	1	1.53	.232	
Electrode x Group	1	0.42	.526	
Stimulus x Group	3	0.21	.888	
Hemisphere x Group	1	0.96	.341	
Electrode x Stimulus	3	0.40	.756	
Electrode x Hemisphere	1	1.36	.258	
Stimulus x Hemisphere	3	0.65	.584	
Electrode x Stimulus x Group	3	0.01	.998	
Electrode x Hemisphere x Group	1	0.06	.809	
Stimulus x Hemisphere x Group	3	0.52	.672	
Electrode x Stimulus x Hemisphere	3	0.62	.602	
Electrode x Stimulus x Hemisphere x Group	3	4.04	.012	*

* Significant at .05 or better.

** Marginal effects requiring further scrutiny.

Appendix C

A preliminary predictive discriminant analysis (PDA) was performed with concern for the significant Group by Midline Electrodes effect for high peak frequency data found in Experiment 1. Specifically, high peak frequency data averaged for each stimulus category of each subject (each subject had a total of 4 data points per electrode site) for sites Fz and Pz were analyzed using a resubstitution PDA in which the data used to develop the discriminant algorithm was then used in classifying subjects as either deceptive or nondeceptive. Moreover, a test of the homogeneity of within covariance matrices revealed that a linear algorithm would best categorize subjects in their corresponding groups, and prior probabilities were equal for both deceptive and nondeceptive categories. Results indicated that 85 % of subjects were correctly classified in their corresponding deceptive or nondeceptive categories. As depicted in the table below, of the 15 % of subjects who were misclassified, 5 % were false positives and 10 % were false negatives.

These preliminary results reaffirm that spectral analyses can be used to differentiate deceptive from nondeceptive individuals. Future research on the use of spectral analysis as a prediction tool for distinguishing deceit from nondeceit will be expanded to include lateral sites and utilization of jackknifing discriminant analyses.

Classification Table for Predictive Discriminant Analysis

Group	Correct Classification	Mis-Classification
Deceptives (n = 10)	8	2
Nondeceptives (n = 10)	9	1